CAN OIL PRICE DEVELOPMENTS EXPLAIN COST OVERRUNS IN PETROLEUM PROJECTS?[1]

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Development projects in the oil industry often have cost overruns. Through analysis of data from Norwegian development projects in the petroleum industry, this paper investigates the common effect of business cycle developments on cost overruns. Lack of capacity and expertise in a tight supplier market yield cost inflation and difficulties in managing projects. Unlike previous analyses of cost overruns, we analyse projects over a long time period to capture the cyclical effects. We document a statistically significant positive relationship between oil price developments and cost overruns, with shocks or surprises to the oil price during the project implementation having a larger impact on cost overruns than the oil price level itself. Cost overrun ultimately leads to reduced competitiveness for the industry, and we discuss consequences and policy implications for business and society of these cost overruns.

Keywords: Cost overruns, petroleum projects, business cycle, oil price

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1. Introduction

In this paper, we study the effect of the business cycle on oil investments and the accuracy of project cost estimates using data from the Norwegian Continental Shelf (NCS). We use the oil price as a proxy for the current industry business cycle and as an indicator for future income expectations. The price of oil is difficult to forecast over longer periods (Hamilton, 2009), and due to long lead-time from investment commitment to production start, uncertainty is substantial for any project in the petroleum industry. By using the oil price as a proxy for the current business cycle and as an indicator for the expectations of future revenues, our study considers the possible cyclicality of oil investment strategies. Our aim is to capture a common factor for cost overruns in petroleum projects linked to the business cycle. Cost overruns also arise due to project specific factors not captured by a common factor such as the business cycles. Cost estimates are adjusted throughout the project due to updates on technical solutions and increased complexity and functionality. Further, uncertainty about ground conditions, the fields size and reserves, may result in delays and increased complexity.

The success of a project in the oil and gas industry is typically considered to affect only the oil producer and the oil exporting country, through their income. However, cost accuracy of oil megaprojects is equally important for consumers and oil importing countries, due to their dependency on oil prices that are influenced by marginal costs. Inefficient oil field projects will increase marginal cost, and consequently add cost to the buyers. Our research on cost overrun therefore has implications for all parties involved in oil trading. Moreover, if the cost accuracy of megaprojects initiated in the domestic oil and gas industry depends on exogenous business cycle drivers, the industry may have a pro-cyclical effect on the domestic economy. Because of major investment in infrastructure and production facilities, the oil and gas industry provides growth opportunities in extraction countries. A study by Nusair (2016) shows that while oil-producing countries in the Gulf Cooperation Council (GCC)[3] experience increasing GDP with increasing oil prices and vice versa, the effect is considerably larger

[3] The Gulf Cooperating Council (GCC) countries include Bahrain, Kingdom of Saudi Arabia, Kuwait, Qatar, Sultanate of Oman, and United Arab Emirates (UAE)

when oil prices are increasing. Norway's GDP is also dependent on the oil price, where the petroleum industry is a dominant industry. The Norwegian government is heavily invested in exploration through tax depreciations from investments and later high tax revenues, the state's direct financial participation in the perceived most profitable fields, and in Statoil through ownership.

Politically, this creates several challenges when considering different approaches to extracting an exhaustible resource to maximize social benefits. Flyvbjerg et al. (2003) study cost overruns in public megaprojects, and find that optimism bias and strategic misrepresentation provide poor decision basis. Consequently, overoptimistic projects are chosen due to their underestimated costs and overestimated revenues. Moreover, since a megaproject is big by definition, it is difficult to cancel after it has been initiated due to already heavy investments. As such, even substantial cost overruns are ignored in order to complete the project. Some of these characteristics of public megaprojects may also be true for megaprojects in the petroleum industry, and short-term and long-term considerations need careful balancing in order to ensure beneficial development and to avoid pro-cyclicality. For instance while Norway, Saudi Arabia and Brazil all have substantial reserves and production, the three governments have different approaches to setting up the industry and revenue collection for society, as well as how they utilize their wealth. Still, by studying the cyclical effects on cost accuracy our study using Norwegian data can provide knowledge of international interest.

Policy makers in oil exporting countries need to consider the incentives for successful implementation of petroleum projects. This is crucial to the industry where marginal cost is expected to increase over time due to complexity of unconventional oil, and several recent papers (van Moerkerk and Crijns-Graus, 2016; Speirs et al., 2015; Bentley and Bentley, 2015) argue that oil supply will be tight in the future. Owen et al. (2010) review the status of conventional oil reserves and suggest that commercially exploited oil is limited and will decline. This is also the conclusion in Benes et al. (2012) whom address the limits to geology as easy and conventional oil reserves are reduced, and the possibilities of technological developments to reduce cost from unconventional and complex oil reserves. Oil supply involves all countries globally and energy security is discussed in several papers (Helm, 2002; Yergin, 2006; Sterling, 2010, Yang et al., 2014). North-America, Europe and Asia-Pacific have been dependent on oil imports, while the Middle-East has provided supply of oil through its abundance of oil resources. To increase future energy security, the world relies on projects with lower cost overruns than typically experienced today. First, this will create profitability for the exporting countries. In addition, and perhaps more importantly, for importing countries profitable projects will provide oil at a lower cost.

For the petroleum industry, cost overruns lead to reduced profitability, and ultimately to reduced competitiveness. Poorly implemented projects require higher capital reserves and consequently increase the cost of capital. Emhjellen et al. (2002) study cost estimation in the petroleum industry, and find that decision-makers utilizing a median cost estimate are vulnerable to asymmetric cost distribution. According to Merrow (2011, 2012), the petroleum industry is particularly poor at delivering at budget and on time. The success rate in the petroleum industry is only 25% and Merrow (2012) argues that one key reason is the petroleum industry's high turnover in project leadership. Moreover, Mishra (2014) at IPA, indicates that projects undertaken on the Norwegian continental shelf (NCS) perform worse than comparable projects undertaken in the Gulf of Mexico (GoM). Their report shows that Norwegian projects less frequently use repeated designs, which are standardized design used in several projects. Considering the increasing complexity of upcoming projects, this may suggest that future projects will continue to experience substantial cost overruns. Other previous studies on NCS relates to drilling and efficiency (see, for example, Mohn and Osmundsen, 2008; 2011 and Mohn 2008).

A report written on behalf of the Norwegian Petroleum Directorate (2013), considers 5 megaprojects on the Norwegian continental shelf. The findings in the report were compared to NOU (1999), a similar report produced by the Investment Committee in 1998. Although there are 15 years between the two reports, the conclusions are similar. First, cost overruns are often identified in early phases. Second, underestimating uncertainty and unrealistic ambitions create too optimistic estimates for project cost and progress. This, together with insufficient time for pre-engineering is the main reasons for the cost overruns experienced on NCS according to the two reports. Unrealistic ambitions and too optimistic estimates are likely correlated with the current business climate and a failure to incorporate the total cost effect of aggregate industry demand for services related to projects when making individual project decisions and projections.

We will investigate projects on the Norwegian continental shelf (NCS) going back to 2000, and compare cost overruns to our proxy for the business cycle. We use yearly data from Ministry of Petroleum and Energy, provided by license holders/operators on NCS that are required to provide a yearly report on actual cost and cost estimates for development projects. Our main finding is that cost overruns are higher, in relative terms, when oil prices increase during project implementation. As such, the industry may be pro-cyclical. Although we are able to identify the oil price as common factors for cost overruns, there is significant heterogeneity in cost overruns. By evaluating the majority of petroleum projects on the Norwegian continental shelf, we assess projects that typically involve complex technological solutions for offshore oil platforms. As consumers and industry will continue to rely on fossil fuel for energy, project complexity will increase since oil and gas fields are becoming more remote and unconventional. Hosseini and Shakouri (2016) use oil price scenarios to simulate future oil supply, and conclude that between 20% and 25% of future oil will come from unconventional oil production. The results from our study will help provide insights on cost overruns related to business cycles for complex projects.

While several papers address the importance of technological and governmental regulation of oil and gas production and extraction, our paper will provide insights on the managerial challenges in securing a stable oil and gas supply as addressed in Andriosopoulos et al. (2016). Cost overruns are inefficient and policy development and monitoring is equally important as forecasting and risk management for a company developing oil and gas fields. Moreover, uncertainties about the closing cost adds capital cost to the operating company, thus limiting the company from undertaking other profitable projects.

Finally, with increasing environmental demands and the remoteness of reserves, the complexity of future projects is likely to increase, emphasizing the importance of policy and incentives for decision-makers to generate efficient projects.

This paper is structured as follows. In section 2, we review petroleum activity on the Norwegian continental shelf and in section 3, we present project cost data provided by the Ministry of Petroleum and Energy from 2000 until 2013. In section 4, we consider key variables related to the petroleum industry and in section 5 we present the regression analysis. In section 6, we provide a discussion of our results.

2. The Norwegian continental shelf (NCS)

There has been oil and gas drilling on the Norwegian Continental Shelf (NCS) since the early 1970s. Figure 1 shows yearly oil and gas production on the NCS. Oil and gas output from the NCS increased steadily until it peaked in 2004 at 264 000 million Sm3 of oil equivalents (o.e.). Recent years have seen a reduction in output and in 2014 production was 219 000 million Sm3 of o.e. This reduction has come from lower oil production, dropping from 181 000 million Sm3 in both 2000 and 2001 to 88 000 million Sm3 in 2014.

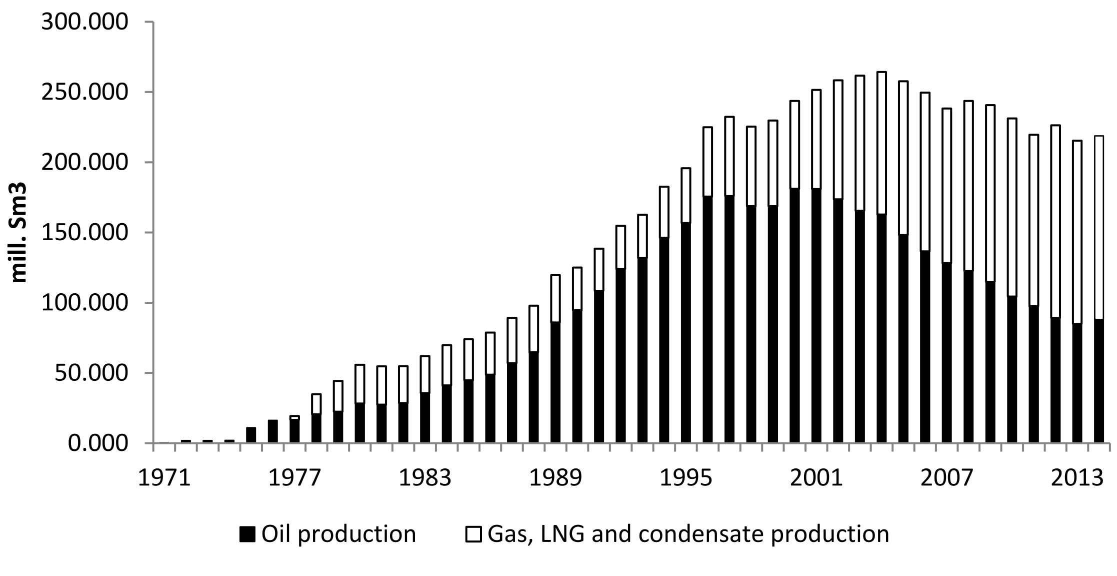

Figure 1 – Yearly oil and gas production on NCS in mill. Sm3

Petroleum activity on the NCSs is important to the Norwegian economy, and petroleum related projects provide huge benefits to the Norwegian society. As oil production declined in the beginning of the 2000s, the Norwegian government added extra incentive for exploration investment with advanced tax deductions in 2005. This provided immediate tax deduction of exploration expenses and immediate repayment of negative tax positions, making it easier for smaller companies to take on exploration projects. As a result, exploration activity increased. Several new companies were established and many existing companies put up business in Norway to take advantage of the new tax regime in the search for new oil and gas fields. While the immediate effect was on exploration, and not on development projects, some of the new fields discovered are in our data set on development projects.

Figure 2 shows how increasing oil prices resulted in an increase in total investments on the NCS. While the total investments in 2000 was just above 50 billion NOK in 2014, the investments quadrupled to 214 billion NOK.

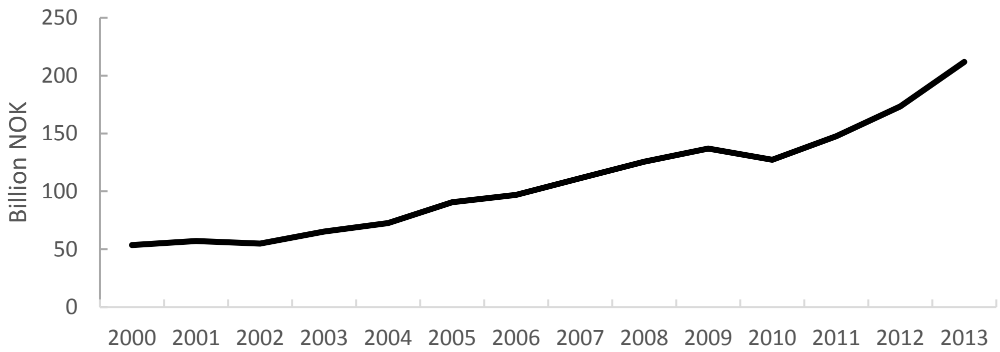

Figure 2 – Total yearly investments on NCS in billion NOK

3. Statistical analysis of Norwegian oil projects

To analyze oil projects on the NCS we use data collected from the Norwegian Ministry of Oil and Energy based on approval of plans for development and operation (PDOs) and special permits for installation and operation (PIOs), pursuant to the Petroleum Act.[4] In total the study considers 80 projects during

[4]http://www.npd.no/global/engelsk/5%20-%20rules%20and%20regulations/guidelines/pdo-pio-guidelines_2010.pdf

the interval 2000-2013. Typically, the projects have estimates over several years, allowing us to compare cost estimates over time, although a project will not cover the entire data period. Consequently, the number of projects active each year varies over the sample, starting with 8 projects in 2000 and ending with 27 projects in 2013 (see Table 1). All cost estimates are inflation adjusted to year 2000 NOK values. Figure 3 shows that on average project size has been increasing throughout the sample period, from 6.5 MNOK to almost 20 MNOK in 2013. This increase can also be seen in the rising share of megaprojects in Table 1 and Figure 4; the cost estimates and actual cost are rising.

Table 1 - number and average cost of projects. Megaprojects >= 10 000 MNOK

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
# megaprojects	2	3	3	4	5	5	7	7	8	6	5	11	13	16
# other projects	6	15	14	16	14	17	15	17	14	11	10	11	11	11
Total projects	**8**	**18**	**17**	**20**	**19**	**22**	**22**	**24**	**22**	**17**	**15**	**22**	**24**	**27**
Average cost (thousand MNOK)	6.5	4.1	4.5	4.2	8.5	7.3	8.3	10.6	10.8	10.5	13.0	14.0	16.1	20.0

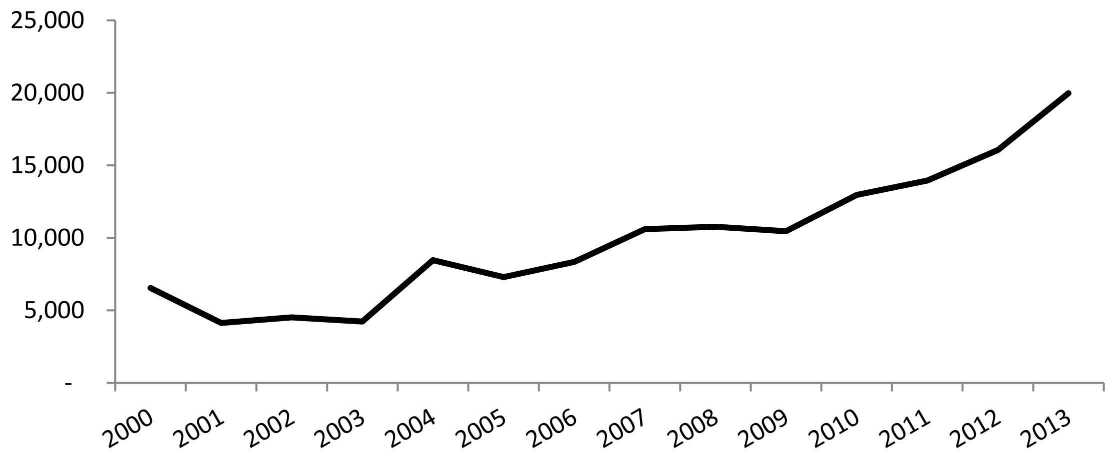

Figure 3 - Average cost estimate in MNOK

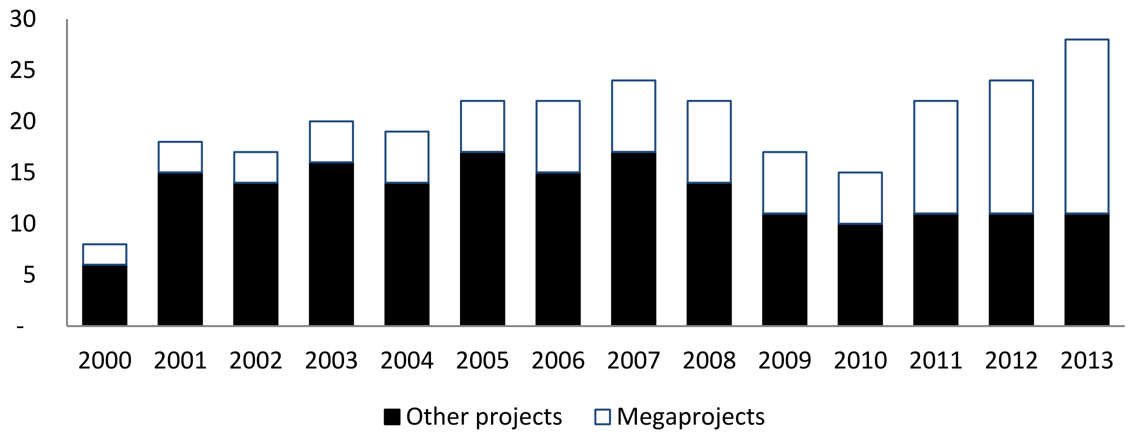

Figure 4 – Number of projects per year. Megaprojects >= 10 000 MNOK

In Figure 5 and Figure 6 we have tried to identify when the cost overrun is typically experienced for a project. It is evident from Figure 5 that cost overruns are accumulated throughout the project lifetime. Moreover, Figure 6 shows that the size of the cost overrun in percentage is increasing with the number of years since project start. While the cost overrun is on average 6 % in year 1, it increases to around 12 % in both the 3rd and 4th year. From these figures we find that both the accumulated cost overrun and the yearly cost overrun increases with the age of the project, with projects lasting more than 4 years having the biggest cost overruns.

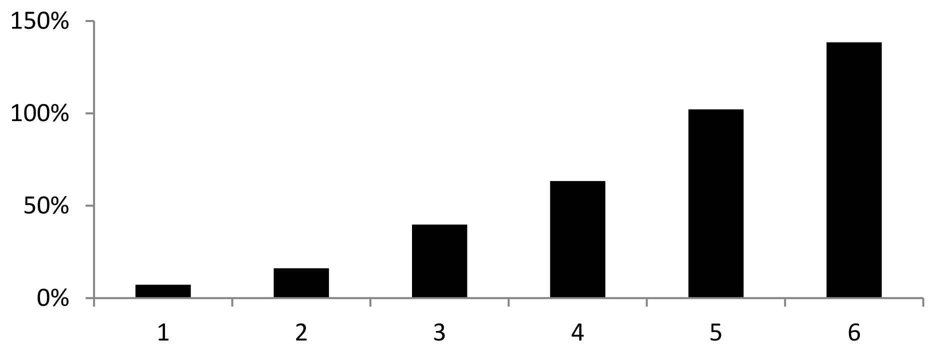

Figure5 - Total cost overrun n years after initial PUD-acceptance

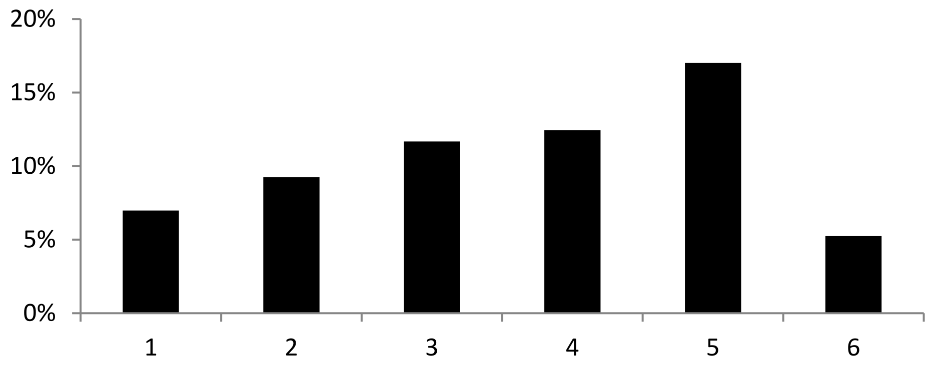

Figure 6 - Yearly cost overrun years after initial PUD-acceptance

4. Empirical analysis on key variables

For the empirical analysis of cost overruns we consider several factors related to the investment level found on the NCS. Figure 7 shows the price of oil (Brent) during the period studied (annual averages). It is evident that both have seen a steady increase throughout the sample period. From only 30 USD/bbl in 2000, the oil price reached 98 USD/bbl on average in 2013.

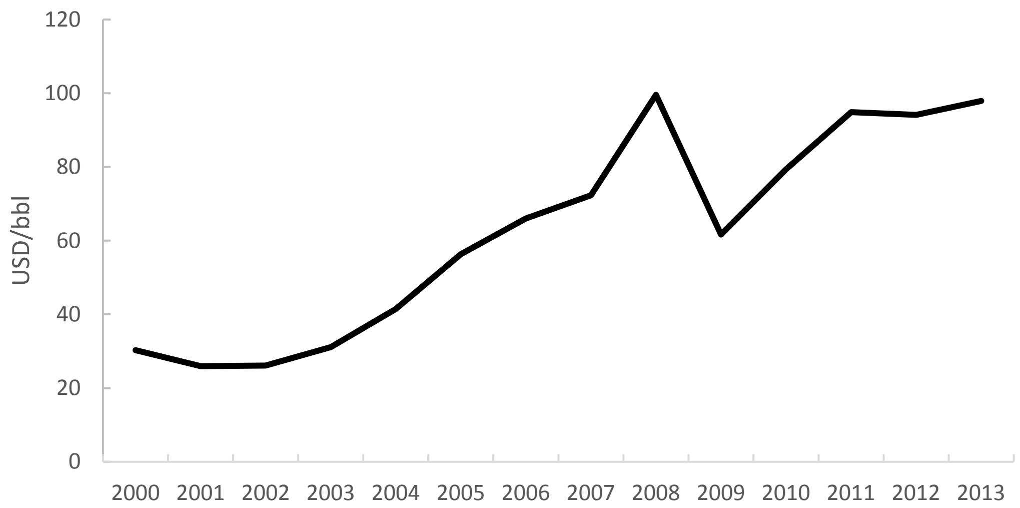

Figure 7 – The price of oil (Brent), 2000-2013

Figure 8 displays average rig rates for floaters, USD per day, on the Norwegian continental shelf. The correlation with the oil price is apparent, as price of rig rates has steadily increased throughout the period, only interrupted during the financial crisis.

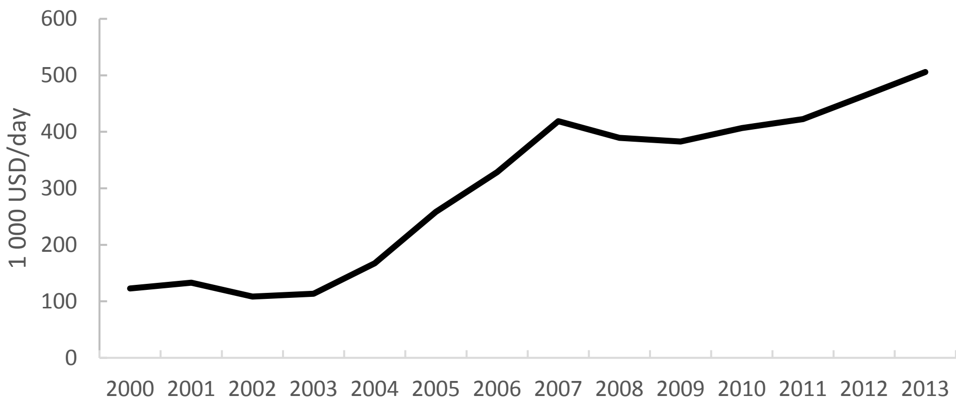

Figure 8 – Average rig rates for floaters, 1 000 USD per day, on the Norwegian continental shelf.

Another cost variable concerning the profitability of a petroleum project is wages. Figure 9 shows the average wage cost from 2000 to 2013. Wages have increased during the entire period, and on average the annual salary was more than 900 000 NOK in 2013 compared to about 510 000 NOK in 2000. In comparison, the average annual salary in Norway in general was 380 000 NOK in 2013.

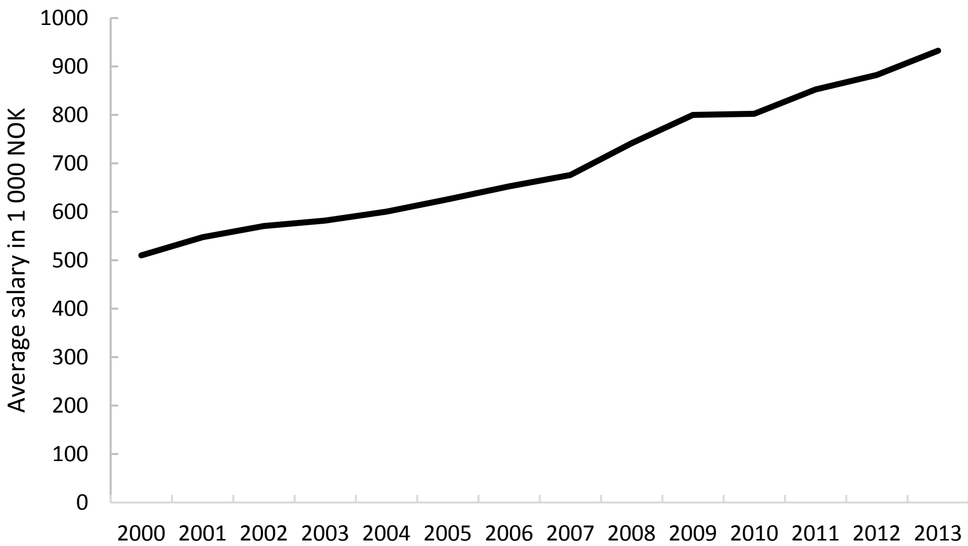

Figure 9 – Average annual wages in 1 000 NOK for employees related to Norwegian petroleum activities

Table 2 and Figure 10 shows correlations between the oil price and key variables related to investment costs on the Norwegian continental shelf. The strong correlation illustrates the importance of cost increases related to the business cycle. With higher energy prices, projected revenues from projects increase, putting pressure on capacity and project development services in a tight supplier market. The strong correlation also highlights the difficulty in isolating effects of individual cost related variables on cost inflation, making it reasonable to aggregate these variables into a common business cycle factor. Since trends in oil prices can be considered exogenous to Norwegian petroleum activity, we represent this factor by the oil price and proceed to investigate their association with average project cost overruns.

Table 2. Correlations between key investment cost variables

	Oil price	Rig rates	Investments	Wages	Employees
Oil price	1				
Rig rates	0.9498	1			
Investments	0.8963	0.9318	1		
Wages	0.8804	0.9101	0.9789	1	
Employees	0.9003	0.9321	0.9701	0.9946	1

Note: Rig rates refer to average rig rates for floaters, USD per day, on the Norwegian continental shelf (source: RS Platou). Investments are total petroleum related investments on the Norwegian continental shelf (source: SSB). Wages are wages for employees related to Norwegian petroleum activities (source: SSB), and employees are number of employees related to Norwegian petroleum activities (source: SSB).

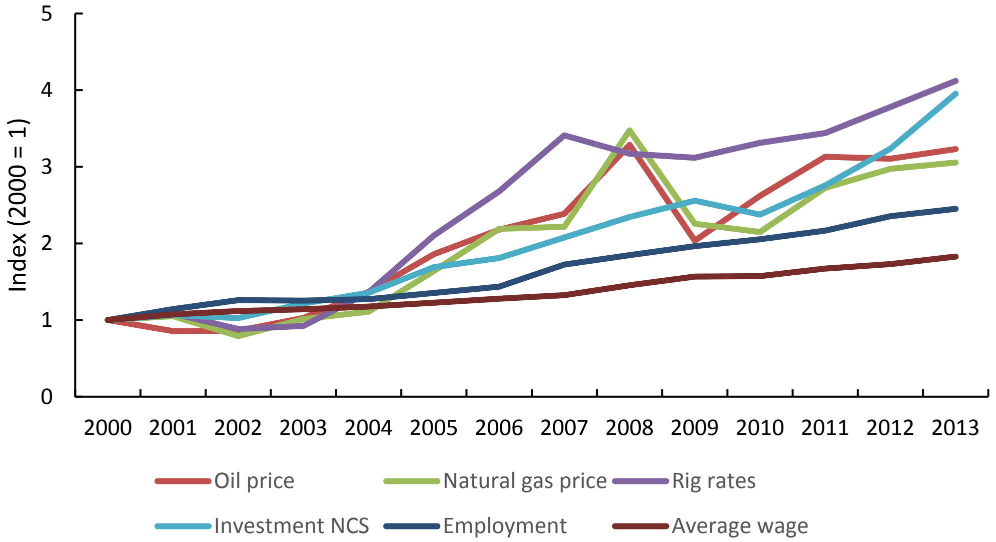

Figure 10 – Key variables indexed to 2000 = 1 from 2000 to 2013. Variables include oil price, natural gas price, rig rates, total yearly investment on NCS, employment related to the petroleum industry and average wages related to the petroleum industry.

5. Regression analysis

For the regression analysis, we use cost overruns as the dependent variable, measured as the percentage difference between initial estimates and updated cost estimates during the project implementation. Independent variables are percentage completion of project, megaproject (dummy variables equal to one for megaprojects) and the annual average oil price and oil price surprise, defined as the percentage change in the oil price from start to end of project implementation. Table 3 shows results from panel data estimation on 80 investment projects from 2000 to 2013.

Table 3. Estimation results, Cost Overruns and Oil price

Variable	Coefficient	t-value	p-value
Intercept	-0.197	-2.170	0.030
Oil Price	0.001	0.980	0.329
Oil Price Surprise	0.167	1.980	0.048
Completion	0.352	3.370	0.001
Megaproject	0.096	1.000	0.316
R^2 (overall)	0.1071		

Note: Random effects estimates with robust standard errors.

Results indicate that the price surprise variable has a significant positive effect on cost overruns, while the oil price level itself has no significant effect. Cost overruns depend more on the development of the oil prices during the project development, than the given price level any year of implementation. This is consistent with adjustments in prices of services due to oil price developments from initial levels affecting cost overruns. The magnitude effect of the surprise variable is such that a 10 percentage-point increase in the oil price during project implementation is associated with a 1.7 percentage-point increase in cost overrun. This indicates that business cycle developments influences cost overruns, as project costs are increasing more in periods of expansion.

Consistent with above we also find that percentage completion of project is associated with higher cost overruns. This simply indicates the reasonable results that cost overruns tend to accumulate and overruns are larger near completion than closer to start. The coefficient is such that after controlling for the other variables, cost overrun at completion is on average 35%. Interestingly, the project size variable controlling for megaprojects do not show significant results when oil price and completion is included in the analysis.

The R^2 of the model is 0.107. Including only the oil price variables, the R^2 of the model is 0.093. Clearly, there is substantial heterogeneity across projects in terms of cost overruns, which a common factor such as the oil price cannot explain. This includes such elements as operator characteristics, reservoir characteristics and project scope and quality changes. However, considering the dependent variable in this analysis is essentially a deviation from cost expectation, not cost itself, it is unlikely to identify a single common factor that explains the majority of the cost overrun.

6. Conclusion and policy implications

We have studied the relationship between cost overruns and business cycle effects using oil prices as a proxy for the state of the business cycle. We find that the oil price surprise, defined as the percentage change in the oil price during project implementation, has a statistically and economically significant positive effect on cost overruns. This provides some empirical evidence that the business cycle affects cost overruns as project costs are increasing more in periods of expansion when oil prices are increasing. Lack of capacity and expertise in a tight supplier market yield cost inflation. The empirical analysis on key variables confirms this. Both rig rates and wages are highly correlated with oil prices when total investments are increasing. This is intuitive since both rigs and workers will be in high demand during growth periods, resulting in difficulties in managing projects and staying on budget.

We find that the largest cost overruns occur late in project implementation. For project managers this emphasizes the importance of cost control, and suggests that deviations from plan should be dealt with immediately to avoid further cost overruns. In addition, this indicates that projects which have recently been initiated may still experience substantial overruns. Considering the recent drop in oil prices, this is likely to have severe impact on these projects' profitability.

Our results highlight that cost estimates need to be evaluated in the context of the general business climate. Herd behaviour leads to cost inflation as supply of project services are inelastic in the short run. To what degree this cost inflation is predictable, and thus cost overruns a result of initial underestimation, remains open to discussion. We also show that while business cycle effects are relevant for average cost overruns, there is substantial variation between projects not captured by the business cycle proxies.

With future oil supply limited by a reduction in conventional resources, future oil production will have a considerable share from unconventional production fields. Thus, with increasing complexity and higher cost more of the projects are likely to be marginal in economic terms. Thus, it is even more important to avoid cost overruns from oil price surprises and increasing oil price.

Our analysis provide useful input to cost estimation. The Norwegian government report on the cost overruns of projects in the North Sea (NOU 1999:11) concluded that there was a 25% increase in development costs from project sanction (POD, Plan for Operation and Development) to last CCE (Capital Cost Estimate) for the 11 oil field projects investigated. Many reasons like unclear project assumptions in early phase, optimistic interpolation of previous project assumptions, too optimistic estimates, and underestimation of uncertainty were given as reasons for overruns. Emhjellen et al. (2002) highlight the possibility that the cost overruns are not necessarily all due to the reasons given, but also to an error in the estimation and reporting of the capital expenditure cost (CAPEX). Usually the CAPEX is given by a single cost figure, with some indication of its probability distribution. The oil companies report, and are required to do so by government authorities, the estimated 50/50 (median) cost estimate instead of the estimated expected value cost estimate. Emhjellen et al. demonstrate how the practice of using a 50/50 (median) CAPEX estimate for the 11 projects when the cost uncertainty distributions are asymmetric, may explain at least part of the “overruns”. Hence, the authors advocate changing the practise of using 50/50 cost estimates instead of expected value cost estimates for project management and decision purposes. We augment their findings by demonstrating that an important and often underestimated cost driver is the effect of the business cycle. Lack of capacity and expertise in a tight supplier market yield cost inflation and difficulties in managing projects. Unlike previous analyses of cost overruns, we have analysed projects over a long time period so that we capture cyclical effects.

Moreover, our findings may contribute to a better understanding and background for economic decisions in the petroleum industry; for resource authorities, oil companies and suppliers in the Norwegian petroleum cluster, and internationally. It may lend support for increased precision of regulations, taxation and administration through improved understanding of corporate behaviour.

Governments in extraction countries are anxious to estimate expected investment in development projects, since they form an essential element of the macro economy. This is particularly the case for Norway. The overall level of activity is also crucial for oil companies, since the macro picture affects cost levels, the supplies market and recruitment opportunities.

Estimating total investment in the petroleum industry is a difficult task. The industry's cyclical nature is often forgotten – particularly for our period of analysis with an almost unprecedented boom which lasted more than 10 years. On the other hand, cost increases are to large extent reversible, so that the investment effect of oil and gas price reductions will be modified. Also, the short-term effect is modified by the fact that on-going development projects are seldom halted.

A common cause of cost overruns is underestimating cost increases directly related to the business cycle. Better estimation of aggregate investment in the petroleum industry would thus improve planning and investment decisions by the companies. It is important to forecast the oil price, but oil companies nevertheless need to strive for consistency in their capital investment planning. Consistency in budgets and investment analysis is crucial for the companies – expected oil and gas prices must be consistent with the expected cost level. We have seen that oil companies in their investment analysis have accounted for increasing oil prices but not fully accounted for the increasing cost that would be the effect of the increase in aggregate investments.

At the same time, it is crucial that macro models are consistent to avoid partial modelling where the effect of a reduction in the oil price is overestimated because the model does not take account of the simultaneous downward pressure on the level of costs such as rig rates and consultant fees. Our research provides input which may alleviate these shortcomings in macro models. At the same time, our analyses of cost overruns highlight crucial factors for cost control.

Previous empirical research on investment patterns in the Norwegian petroleum sector is related to exploration, see Mohn and Osmundsen (2008, 2011). We look at the major component of petroleum investment – development projects. Fluctuations in development investment in response to changes in oil and gas prices are considerably smaller than for exploration spending – partly because longer lead times and low success rates make exploration more risky and thus more price sensitive, and partly because exploration unlike development can be reduced at short notice.

It is worth noting that the factors contributing to cost overrun are likely to have the opposite effect in the current negative investment climate of falling prices. Idle capacity in the supply industry implies tough competition and lower prices, and probably higher average quality. The oil companies also have more competent personnel to manage projects. Drilling is a prominent example of cost reductions. In times of economic recession, as we now experience, rig rates decrease while drilling productivity increases, which both contribute to decrease drilling cost[5]. We now see projects with cost underruns, e.g., the giant Sverdrup field at the NCS. This is particularly important at these times when many firms are struggling because of low oil price and little activity. The decreasing drilling cost can now prove continued operation.

Policy implications of the cost overruns may be drawn for oil companies and governments in extraction countries. Oil companies need to be careful to underestimate investment cost in times of boom. Instead, they may attempt to make countercyclical investment, taking advantage of low prices in periods of low aggregate activity. To achieve this they need to be financially strong when other

[5] Osmundsen et al. (2010; 2012).

companies are weak, by maintaining a high equity share or by being vertically integrated and thus having a revenue stream less affected by the oil price. For governments the goal must be to achieve a more stable aggregate investment level in the oil industry. This is a difficult task. Regular opening of new acreage might help but is not a precise means to control the activity level. Using the tax system actively to stabilize investment levels is often futile, as oil companies need stable taxation to enter into large and irreversible investments. At any rate, governments typically react too slow and thereby risk to reinforce the business cycles. One example is the Norwegian government's reduction in the uplift to reduce the investment increase, May 2013. The tax increase came at the top of the business cycle and had the effect of reinforcing the current situation of underinvestment.

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